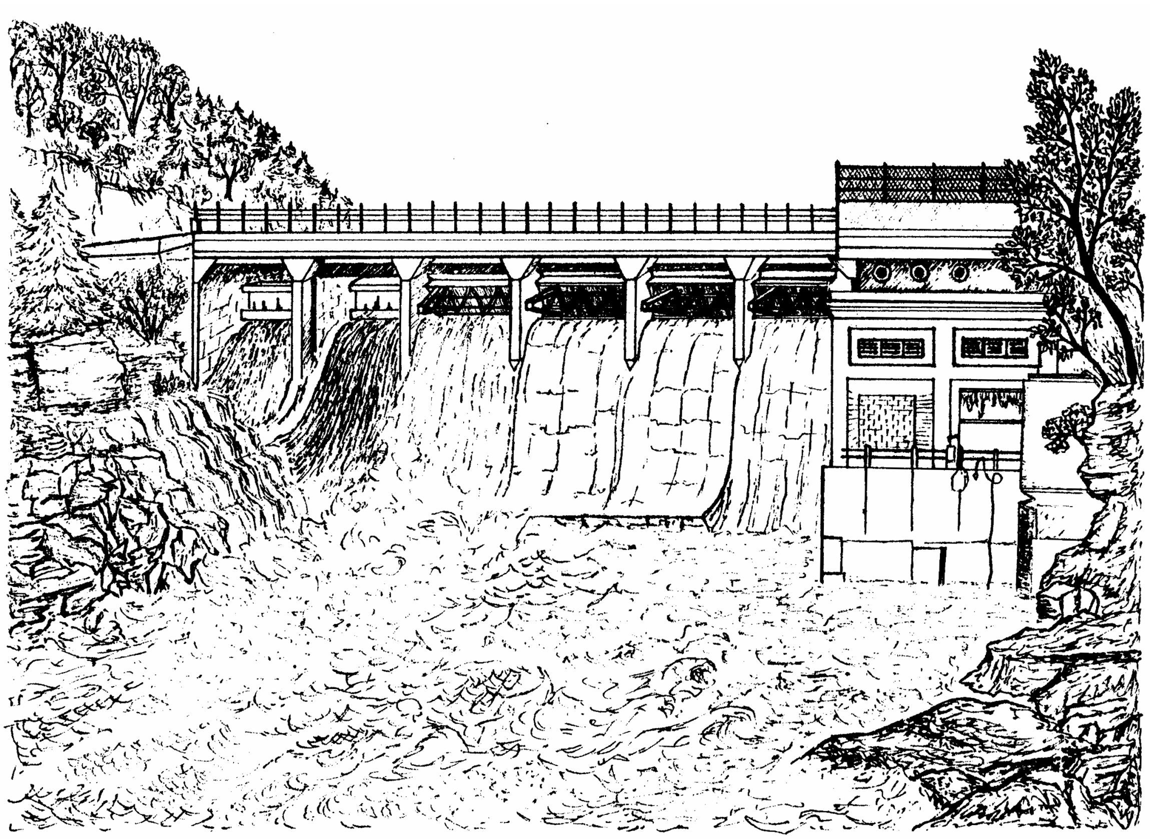
EXECUTIVE SUMMARY

The Rapidan Dam Research Project:

Environmental impacts of converting a run-of-the-river low head hydroelectric dam to a peaking operation.

Context, Findings, and Needs



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Twenty years have lapsed between the Rapidan Dam Research Project: Environmental impacts of converting a run-of-the-river low head hydroelectric dam to a peaking operation and the present consideration of dam removal. During these 20 years the national as well as local interest and emphasis has shifted from renovation to removal. Further, the scope and breath of the decision matrix has greatly increased. Following is a brief discussion of the context of the then and the now, the study findings, and the future needs.

THEN

The Rapidan Hydroelectric dam was built in 1910-1911 as a stimulus to the growth of Mankato. The dam was severely damaged in the spring flood of 1965 and remained idle as a run-of-the-river dam until 1985. Due to the persistence and enterprising spirit of two men, Blue Earth County Commissioner Bill Maher and Kenneth Lever, Rapidan Redevelopment Ltd. Partnership in combination with the 1973 OPEC Crisis, 1978 PURPA, investment tax credits and appreciated depreciation schedules the dam was retrofitted for peaking. Interestingly, at that time the same debate was going on as to remove, retrofit to peaking, tearing off the top to create a rapids, fill the dam up with concrete, etc.

As a part of the dam relicensing, the Minnesota Department of Natural Resources, Minnesota Pollution Control Agency, Blue Earth County, and others required, through stipulation, that the environmental impacts of conversion be examined. Minnesota State University, Mankato at that time, Mankato State University, was contracted to do water quality, sediment, synthetic organics and macroinvertebrate study while MDNR Fisheries did the fish study. It is important to note as stated by Jack Skrypek, ecological manager at that time, in the MDNR's Division of Fish and Wildlife, that peaking is not a new idea for dams, but there have never been studies of its effects (Weiss, P. 1983).

NOW

Whereas the emphasis in 1985 was energy, and especially peak energy, by the turn of the century the emphasis switched to restoration of free flowing rivers.

> To quote Doyle, M.F. et al. 2000:
> "The American environmental movement is currently witnessing significant changes in accepted approaches to river management. Rivers once developed and altered for human benefits are being restored in a variety of manners and magnitudes, often with the sole intention of environmental enhancement. River restoration to date has primarily consisted of enhancement of geomorphic and habitat features along a specific reach of a river, or the enhancement of water quality via regulation of point and non point source pollution. However, such measures are only partially capable of accomplishing the goal of restoration: to return an ecosystem to an approximation of its pre-disturbance condition (Schmidt et al., 1998). Dams remain a significant limitation to overall restoration efforts, as there are fewer than 60 rivers with 100 km or more of free-flowing channel in the contiguous U.S. Hence, the recent realization of dam removal represents a significant development for the potential restoration of riverine environments."

There are more than 75,000 inventoried dams in the U.S. (greater than 1.8m (6 ft) high with at least 0.2 km (50 acres) impoundment (Shuman, 1995). American Rivers et al., 1999 lists the individual states with the number of dams removed along with the heights of the dams and years removed. Of the over 400 dams removed, 73 are from Wisconsin. Minnesota ranks tied as 13th through 18th with 9. The majority of the dams removed have been post 1990 and less than 5 meters in height (American Rivers et al., 1999).

The decision making matrix for removing, converting, stabilizing, etc dams has been expanded since Blue Earth County first addressed the issue in the late 1970's. These include physical, ecological, and societal issues. Physical issues include: release of sediments, changes in channel morphology, changes in water quality, changes in floodplain, etc. Ecological issues include: fish movement changes, floodplain wildlife changes, changes in wildlife corridors, impact of flow changes, etc. Societal considerations include: aesthetics, historic/local community value, economics, recreation, etc. All of these and others need to be a part of the matrix. The most difficult task is assigning weights to each issue. See Doyle, MW. 2000, and Shuman, J.R. 1995 for an excellent discussion of matrix parameters. Many parameters for the removal only option, have been covered, in preliminary fashion, by BARR Engineering, Blue Earth County, MPCA and MDNR, 2000.

The purpose of this report is to provide the decision makers, the Blue Earth County Board of Commissioners, information on the impact of the conversion to peaking versus maintaining as run-of-the-river operation, which is part of the overall decision making matrix for Rapidan Dam.

FINDINGS

The permit for the relicensing of the Rapidan Dam of Blue Earth County, Minnesota, required a study of the impacts of the conversion of run of the river to fluctuating flow (peaks) on water quality, sediments, synthetic chemicals and aquatic macroinvertebrates. The study was for the Blue Earth County Board of Commissioners and was conducted in 1983 (pre-operation) run of the river through 1985 (peaking).

Water Quality

Introduction

The water quality component has addressed three questions pertaining to the Rapidan Reservoir and the peaking operation of the Rapidan Hydroelectric Dam.

1. Did the Rapidan Reservoir impact the concentrations of the water quality and Particulate Organic Matter transport parameters, during the run-of-the-river baseline sampling periods in 1984 and 1985?
2. Did the peak power generations (peak-events) of the hydroelectric facility impact the concentrations of the same water quality and OM transport parameters independent of the reservoir's impacts?
3. Were the water quality and OM transport parameters impacted differently by different types of peak-events, i.e. a peak-event preceded by many consecutive non-generation days as compared to a peak-event preceded by a run-of-the-river operating mode and antecedent storm events?

To try to determine the answers to these questions, the concentrations of eleven water quality parameters and four size classifications of OM were determined during samplings in 1984 and 1985 at eight sites along a 51.8 river km (32.2 river mi) stretch of the Blue Earth River (Attachment #1), and three peak power generations (peak-events) in 1985. The samplings in 1984 and the non peak-event samplings in 1985 were used, along with historic data from MPCA records, to establish a baseline for each parameter, which the peak-event data were compared to. The impact on the water quality parameters and OM transport by a peak-event, preceded by many consecutive non-generation days, was compared to impacts caused by two peak-events preceded by run-of-the-river operating conditions; differences in the number of turbines operating and antecedent storm events.

1. Impact of the Rapidan Reservoir

<u>Water Quality Parameters</u>

The Rapidan Reservoir showed evidence of directly impacting the mainstem concentrations of five of the eleven water quality parameters in question, during the baseline sampling periods in 1984 and 1985. The reservoir appeared to act as a trap sometimes, and thereby decreased the downstream concentrations of the parameters Total Phosphorus, Filterable Phosphorus, Total Non-Filterable Residue (TNFR), and Total Volatile Non-Filterable Residue (TVNFR). The reservoir appeared to increase the downstream concentration of the fifth parameter, Nitrite-Nitrogen, within the reservoir and a portion of its tailwaters, which may be due to the oxidation of ammonia to Nitrite-Nitrogen.

<u>OM Transport Parameters</u>

The reservoir appeared to act as a trap for Coarse Particulate Organic Matter (CPOM), thereby decreasing its downstream concentrations during the baseline sampling periods in 1984 and 1985, but did not act as a trap for the Fine Particulate Organic Matter (FPOM), Very fine Particulate Organic Matter (VPOM) and Dissolved Organic Carbon (DOC).

2. Impact of Peak Events

<u>Water Quality Parameters</u>

The questions addressed here are whether significantly higher levels for the water quality parameters, above baseline, were reached as a consequence of the peaking and whether the peaking event results in an acute increase in the water quality parameters. Keep in mind that Site 3 is above the reservoir and represents draw down whereas Sites 5, 6 and 8 are below the dam and represent progressive downstream flow from the reservoir. During the 8/9 event we established multiple sampling sites at Site 5 across the river and the data revealed total mixing with similar water quality at all sites. As a result, of this mixing, we were able to move downstream and added Site 6 on 8/20 and Site 8 on 8/26. As a consequence of increasing sites, the peak-event data described represents three events at Site 5, two events at Site 6 and one event at Site 8. Since these peak events are acute events in nature this discussion will focus on highest levels reached at each site. Also, the baseline highs for 1985 cover the period from 6/10 to 9/15 whereas the three peaks all occurred in August.

The Water Quality Parameters maximums are shown in Table I and revealed the following:

- The peaking highs for August surpassed the baseline (June-September) in 24 out of 74 cases. Nineteen were downstream of the dam (eight at Site 5, seven at Site 6 and four at Site 8). Also, all three sites below the dam reached higher levels than baseline for Organic Nitrogen, Total Phosphorous, Total Non-Filterable Residue and Total Volatile Non-Filterable residue.
- The pre-event, startup, to maximum event levels during the three events revealed that in 84 of 91 cases the events raised the maximum concentration of the parameters. Great increases were seen at all sites with maximums of 10x at Site 3 (Ammonia), 7x at Site 8 (Total Non-Filterable Residue) and 4x at Sites 5 (Ammonia) and 6 (Ammonia and Total Non-Filterable Residue).

The maximum for peak events increased progressively downstream of the dam for Organic Nitrogen, Nitrate Nitrogen, Total Phosphorous, Total Non-Filterable Residue, Total Volatile Non-Filterable Residue, and pH. This indicates that input from the sediment, including rewetting, was playing a role, however further research is needed in this area.

The above observations from the Water Quality Parameters data revealed important impacts of the peaking operation. Since the peaking is an acute event, the emphasis is placed on the maximum concentrations and changes during peaking. We observed acute, often excessive, fluctuations which occurred in a short period of time. These changes were often amplified downstream. These rapid changes in water quality occurred in a closed system in that there were no tributaries from the dam to the Minnesota River except the LeSueur (Site S7), no immediate run off due to rainfall or inflow, and can be attributed directly to the peaking. That some of the highest levels were found on 8/30, following two previous flushings, is most interesting and raises questions on the contribution dynamics of the river sediment, both wet and rewetted.

Table I: Water Quality Parameters 1985 baseline and peaking maximums in mg/L and ug/L. (Table XXX from the Rapidan Dam Research Project: Environmental impacts of converting a run-of-the-river low head hydroelectric dam to a peaking operation.)

	Site	Date	Ammonia Nitrogen (mg/L)	Organic Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Nitrite Nitrogen (ug/L)	Total Phosphorous (mg/L)	Filterable Phosphorous (mg/L)	Total Non-Filterable Residue (mg/L)	Total Volatile Non-Filterable Residue	Conductivity (uohms/cm^2)	pH	Water Temperature (Degrees C)
Upstream	1			(1.99)	(13.43)	(8)	(.36)		(359)	(46)	(700)	(7.99)	(27)
	2			(2.03)	(12.49)	(7)	(.47)		(295)	(44)	(720)	(8.10)	(27)
	3	 8/9 8/26 8/30	 .07/.10 0/.03 .04/.41	(1.93) 1.11/1.28 1.50/1.63 1.46/1.60	(10.99) .12/.14 .11/.32 1.22/1.44	(10) .32/.69 .09/4.64 7.06/7.06	(.26) .18/.19 .12/.17 .21/.24	 0.048/0.049 0.042/0.039 0.049/0.042	(108) 75/69 38/62 59/64	(20) 16/23 24/31 27/31	(730) ___/___ 625/675 650/650	(8.17) ___/___ 8.27/8.41 8.00/8.35	(25) ___/___ 21.5/23.0 20.5/22.0
	4			(2.09)	(12.49)	(17)	(.26)		(131)	(35)	(740)	(8.23)	(30)
	Dam												
Downstream	5	 8/9 8/26 8/30	 .08/.18 .05/.21 .07/.07	(1.78) .98/1.41 1.22/1.51 1.31/1.82	(13.09) .20/.21 .14/.17 .17/.23	(17) 1.16/1.91 .09/.55 .46/1.48	(.23) .15/.27 .13/.16 .17/.21	 0.058/0.074 0.034/0.044 0.036/0.042	(84) 49/142 38/46 57/73	(17) ___/23 15/31 24/31	(740) 751/759 675/685 600/625	(8.31) 7.61/8.00 8.15/8.20 7.91/8.08	(25) 26/26 22/22.5 21/22
	6	 8/26 8/30	 0/.60 .05/.26	(1.65) .99/1.42 1.22/1.72	(12.99) .27/.33 .22/.31	(11) 1.39/1.57 .64/.74	(.23) .13/.31 .15/.39	 0.044/0.049 0.049/0.075	(91) 31/157 29/150	(21) 18/35 16/37	(740)	8.50 8.12/8.21 7.79/8.02	(28) ___/___ ___/___
	7			(1.64)	(15.43)	(20)	(.39)		(263)	(40)	(740)	(8.39)	(26)
	8	 8/30	 .05/.08	(1.51) 1.70/1.89	(13.99) .17/.38	(11) .15/.92	(.30) .16/.36	 0.042/0.044	(122) 42/310	(20) 20/54	(700) 630/650	(8.59) 8.34/8.43	(27) 23.5/25.0

Key (a) : (Highest value – baseline 85)

x/y : Pre event level/max event level

OM Transport Parameters

The Organic Matter maximum transport breakdown revealed the following (Table II) :

- The peaking highs at particular sites exceeded the baseline maximums for those sites in 17 of 36 instances with 13 below the dam. Six were in the very fine particulate organic matter category, five in fine particulate organic matter, three in dissolved organic carbon and three in coarse particulate organic matter. Four of the 36 were above the dam and involved the smaller sized fractions. Only fine particulate matter at Site 8 exceeded the total baseline seasonal maximum.
- The pre-event, startup, to maximum event levels revealed that in 33 of 36 cases the events raised the concentration of the parameters. Greatest increases were seen at Site 8 ranging from 60% to almost 500%. The increases were greater as one progressed downstream of the dam. Also, in general, these greater increases as one progressed downstream of the dam indicated recruitment from the deposited sediment. Further, the increases were often greater as one progressed from peak one to peak three. This is interesting because the three peaks were all within 18 days and as stated above cannot be attributed to reservoir release.

These observations revealed important impacts of the peaking operations. We observed short-term, often excessive, acute fluctuations which are often amplified as we move progressively down river. From an organismal standpoint, this creates an altered environment, which is unpredictable and demands a different survival strategy for macroinvertebrates and fish.

3. Impact of Variations in Peak Events.

Water Quality Parameters

The 8-9 peak-event was characterized by 21 consecutive non-generation days. The 8-26 and 8-30 events were preceded by run-of-the-river operating conditions (one turbine was running constantly). At site S5, the 8-9 event produced greater increases in concentration from the pre-event concentration for certain parameters, as compared to the August 26th and August 30th events. The parameters most impacted by the August 9th event included Organic-Nitrogen, Total Phosphorus, TNFR, and TVNFR. The remaining water quality parameters possessed relatively similar increases in concentration at S5 during all three peak-events.

OM Transport Parameters

The August 9th event produced a greater increase from the pre-event concentration for the OM size classification FPOM at S5, than did the latter two events. The remaining three size classes possessed relatively similar increases in concentration at S5 during all three peak-events.

Table II: Organic matter transport; 1985 baseline and peaking maximums in mg/l. (Table XXXI from the Rapidan Dam Research Project: Environmental impacts of converting a run-of-the-river low head hydroelectric dam to a peaking operation.)

	Site	Date	Course Particulate Organic Matter	Fine Particulate Organic Matter	Very Fine Particulate Organic Matter	Dissolved Organic Carbon
Upstream	1		(1.7)	(6.5)	(29.2)	(6.7)
	2		(0.4)	(3.2)	(29.7)	(5.9)
	3	 8/9 8/26 8/30	(1.2) 0/0.5 0.6/0.5 0.3/1.0	(4.8) 1.2/1.3 1.4/3.4 2.1/2.3	(17.1) 13.7/16.5 16.6/21.8 19.1/21.1	(5.8) 3.9/4.6 6.5/7.6 6.8/7.2
	4		(0.5)	(3.6)	(26.7)	(6.1)
	Dam					
Downstream	5	 8/9 8/26 8/30	(1.2) 0.4/1.6 0.5/0.6 0.1/0.5	(2.3) 1.4/4.1 3.7/3.7 1.7/2.8	(15.4) 14.3/15.4 12.8/15.2 16.5/21.0	(9.1) 5.8/7.3 4.6/5.1 6.9/8.0
	6	 8/26 8/30	(0.4) 0.6/0.7 0.8/0.7	(5.4) 1.5/5.7 1.5/3.1	(18.5) 11.7/22.5 16.1/26.2	(6.3) 3.1/4.4 4.3/5.8
	7		(0.6)	(1.4)	(18.8)	(7.4)
	8	 8/30	(1.6) 0.3/1.0	(2.3) 2.1/10.4	(13.2) 15.0/26.1	(6.3) 5.3/8.6

Key (a) : (Highest value – baseline 85)

x/y : Pre event level/max event level

Sediments

Introduction

The sediment component addressed five questions pertaining to the Rapidan Dam Reservoir, run-of-the-river and the peaking of the Rapidan Hydroelectric Dam.

1. Did the Rapidan Dam Reservoir impact the concentrations of suspended sediments in transport during the baseline sampling periods of 1984 and 1985?
2. Did the peak power generations (peak-events) in 1985 of the hydroelectric facility impact the concentrations of the sediment fractions?
3. What is the nature of the surficial sediment in the reservoir (grain-size and percent organic) and do the old channel surficial deposits differ from the submerged flood plain?
4. Did the peaking-events affect the surficial reservoir sediments?
5. What are the upstream sediment sources in regards to the bed load?

1. Impact of Rapidan Dam Reservoir on Sediment Transport During Baseline Flow (Run-of-the-River)

- Total Suspended Solids

  The reservoir acted as a sediment trap in the two early periods (June-July) with no apparent affect in the late periods (August-September) even though the wet/dry cycle reversed itself from 1984 to 1985.
- Coarse and Medium Silt

  No relationship was observed between a higher percentage coarse and medium silt to suspended sediment during baseline.
- Fine and Very Fine Silt

  In most of the baseline data the fines and very fine silts made up the smallest component of suspended sediments. There were no fine and very fine suspended sediments in the later period of 1985 in 16 of 24 samples. The reservoir did not appear to be acting as a settling basin and no apparent relationship to suspended sediment was observed.
- Clay

  Clay, during the baseline samplings, represented the dominant component of suspended sediment. The dry seasons averaged slightly higher mean percents than the wet seasons even though these two reversed themselves in 1984 and 1985. This is undoubtedly a transport energy relationship. There was no discernable relationship between suspended concentrations and percentage clay.
- Silt and Clay that is Organic

  The baseline suspended sediment in the silt-clay category that was organic generally increased from early season to late and averaged around 50 percent. This indicates algal development and/or organic aggregation. The reservoir was a source in three out of the four seasons (early and late 1984 and 1985) and no significant progressive downstream effect was observed.
- Clay that is Organic

  The baseline suspended sediment that is organic in the clay fraction is generally higher than the clay silt category in both periods of both 1984 and 1985. This indicates organic aggregates of clay sized particles. No observed correlation was seen between total suspended solids and percent organic clay. No consistent, progressive downstream pattern was observed.

2. Impact of Peak Power Generations (peak-events) in August, 1985 on Suspended Sediments

A comparison of maximums, both 1985 baseline and peaks, by site is shown in Table III.

Suspended Sediments (g/l):

- In three of four sites (except Site 6) the maximum in peaking is not as high as baseline high.
- At all sites, the pre-event is surpassed during each peaking event.

Percent Coarse and Medium Silt:

- In one of four sites a peaking maximum exceeded the baseline maximum (Site 5).
- In seven out of nine peaking site dates the peaking exceeded the pre-event level. The two exceptions were at Site 3 above the reservoir.

Table III: Suspended Sediment in transport, 1985, baseline and peaking maximums (Table XXXII from the Rapidan Dam Research Project: Environmental impacts of converting a run-of-the-river low head hydroelectric dam to a peaking operation.)

	Site	Date	Suspended Sediments (g/l)	Percent Coarse and Medium Silt	Percent Fine and Very Fine Silt	Percent Clay	Percent of Suspended Sediment Silt and Clay that is Organic	Percent of Suspended Sediment Clay that is Organic
Upstream	1		(.29)	(77)	(48)	(100)	(47)	(86)
	2		(.29)	(68)	(35)	(100)	(66)	(100)
	3		(.28)	(70)	(88)	(74)	(82)	(100)
		8/9	.22/.25	47/46	0/29	53/92	57/92	___/86
		8/26	.14/.16	47/16	0/29	53/100	64/83	91/96
		8/30	.10/.26	24/52	0/50	76/76	40/75	46/79
	4		(.26)	(55)	(92)	(100)	(78)	(89)
	Dam							
Downstream	5		(.29)	(80)	(35)	(100)	(88)	(80)
		8/9	.21/.28	58/59	8/52	34/100	35/89	63/72
		8/26	.12/.18	51/87	23/75	26/70	45/89	23/67
		8/30	.16/.25	18/68	36/40	46/100	41/77	33/87
	6		(.19)	(84)	(40)	(82)	(58)	(83)
		8/26	.12/.44	25/68	0/43	75/55	52/54	66/78
		8/30	.20/.29	0/84	80/20	20/100	38/55	8/86
	7		(.24)	(95)	(69)	(50)	(94)	(94)
	8		(.48)	(76)	(22)	(79)	(86)	(92)
		8/30	.11/.34	59/62	0/56	41/69	30/66	55/84

Key (a) : (Highest value – baseline 85)

x/y : Pre event level/max event level

Percent Fine and Very Fine Silt:

- Only at Site 3, above the reservoir, did the baseline maximum exceed the peaking maximum for all three events.
- In eight out of nine peaking sites dates the peaking exceeded the pre-event.

Clay:

- In two out of four sites the peaking maximum exceeded the baseline maximum.
- In seven out of nine peaking site dates the peaking exceeded the pre-event.

Percentage Organic:

1. In all cases of the percentage of suspended sediment, silt and clay, that is organic and the percentage clay, that is organic, exceeded the pre-event levels.
2. The vast majority of the suspended sediment in the dominant clay category is organic
3. Peaking in most cases increases the percent organic, often between two to three times, but seldom exceeds the baseline maximums for the sampling season.

3. **Nature of the Surficial Reservoir Sediment (Grain-size, and Percent organic) and relation to the old channel.**

Twenty one transects were sampled from V (upstream) to C (at the dam) (Attachment #2). Transects V though N were flooded only during the reservoir storage phase. Gravels and very coarse sand were seen furthest up the Blue Earth and the mouth of the Watonwan Rivers. Sands were dominant in the old river channel from the start of the reservoir through N, the last transect before the permanent reservoir. The transects V through N showed a general increase in silts and clays with a corresponding decrease in sands which became finer, all indicating a transition to a lower energy environment. From transects M through C, within the old river channel there is almost no gravel or very coarse sand. From transect F and increasing through C, the sediments become coarser in the channel probably because of the sucking of the finer sediments by the turbines. Downstream of transect N, the percent of coarse and medium silt increased slightly within the channel and more so outside the channel. These findings are all before the peaking events began and represent run-of-the-river.

4. **Comparison of the Pre and Post Peaking Reservoir Surficial Sediment, July to October, 1985.**

The sampling was to compare the earlier very dry period, run-of-the-river, to the abnormally wet period, post peaking. Any effects found can not be definitely assigned to rainfall or peaking, however the peaking events with their major draw downs at Site 3 (between transect Q and P) appear to have had the dominant hydrologic impact. There was a change to a very high ratio of coarse (sand) to fines (silts and clays) in the river channel from W through M. This reach represents the pre-continuous reservoir. This was probably the result of the significant draw down and therefore pulling of fine sediment into the reservoir caused by peaking. Within the reservoir proper we see the reverse which indicates the deposition of stripped fine sediment from upstream.

5. **Pre Reservoir Expansion Bed Load Sources**.

A 1983 reconnaissance of the river channel, now within the reservoir, and downstream of the dam revealed a large number of sand dunes often as high as one foot. The grain size distribution of sands as well as other sediment categories appear to be quite similar between the Blue Earth and Watonwan Rivers. Further, the upstream-downstream sampling at major cliff locations show no significant differences indicating that the rivers are similar, in equilibrium, and that upstream sources of sand exist. In 1985, with the restoration of the dam completed and filling of the expanded reservoir, the surface bed load deposits were not observed or documented. This is consistent with the increased impounding that both slows the flow back upstream and allows for the deposition of fines on top.

Summary

The August 9th event, which was preceded by 9 days of no rain, showed a significant increase in suspended sediment at both Sites 3 and 5. The August 26th event, which was immediately preceded by abnormally high precipitation, remained close to baseline at Sites 3 and 5, but showed a dramatic 400% increase at Site 6 indicating river bed scouring. The August 30th event, preceded by a 2.62 inch rainfall the day before, showed a significant increase in suspended sediment at Site 3. This was probably due to upstream loading due to the rain. Site 8 also increased significantly. It appears that the suspended sediments increased significantly the further downstream you go.

It is clear that rapid, acute rises do occur during peak events especially in the fines and clays and that these fines and clays have a high organic content.

Synthetic Organics

Introduction

The synthetic organics component addressed two questions pertaining to the Rapidan Dam Reservoir and the peaking of the Rapidan Hydroelectric Dam.

1. What synthetic organics are present?
2. Does the peak power generation (peak-events) in 1985 of the hydroelectric facility impact the concentration of any synthetic organics detected?

1. Synthetic Organics Found.

Only two distinct peaks were found, with neither being a chlorinated pesticide. The two peaks were identified as pthalate plasticizers: Butyl octyl pthalate= 1, 2-Benzenedicarboxylic acid, Butyl octylester and 2-butoxyethyl butyl phthalate=1, 2- Benzenedicarboxylic acid, 2-butoyxethyl butyl ester. This is consistent with recent agency findings for the late summer time of sampling 8/9, 8/26 and 8/30 (Metropolitan Council Environmental Services, et al., 2001).

2. Impact of the Peak Power Generation (Peaking Events).

The behavior of the pthalates during the peaking events, although not of great significance by and of itself is important as an indicator of what some other synthetic organics and other endocrine disrupters could exhibit if present.

Significant fluctuations in pthalates were found at Site 3 which is above the reservoir and experienced draw down during all three peaks. It appears the reservoir was not a source of pthatlates during the peaks (Site 5) but rather they were either diluted or settled out from Site 3. No clear relationship to turbidity was uniformly observed.

Sites 6 and 8 (further downstream) showed a closer relationship of pthalates to turbidity.

Aquatic Macroinvertebrates

Introduction

The aquatic macroinvertebrate component has addressed the question: Did the peak power generation (peak-events) of the hydroelectric facility impact the macroinvertebrate community?

Samples were collected over a three year period beginning in 1983, the year before dam operation, and during dam operation from late 1984 through 1985. Data were analyzed with respect to total abundance, taxa richness, community diversity and feeding functional groups.

Macroinvertebrate total abundance, richness and community diversity declined at sites immediately downstream of the dam in 1984 and 1985. The abundance of functional groups also declined at sites immediately below the dam although percent composition of functional groups remained relatively constant throughout the study. The site most distant from the dam showed minimal changes in the macroinvertebrate community suggesting a gradient of impact. Since feeding functional groups exhibited declines in abundance but did not change in percent composition, it is likely that fluctuating flows, and not food availability, were the reason for changes in the macroinvertebrate community.

Abundance

The mean total abundance of organisms below the dam at sites 5e through 6 declined from 1983 to 1984 and persisted into 1985. In general, the mean total abundance of organisms was lower at station 1's (shallow water) than at Station 2's (Deeper water) for each site downstream of the dam. This decline in mean total abundance of organisms below the dam seemed to be the result of fluctuating flows caused by the dam operation as these same reductions in abundance were not observed in the Le Sueur River (the control) or Site 2 upstream of the reservoir.

Richness

A total of 16 fewer genera were collected in Surber samples from the Blue Earth River in 1985 than in 1983 (45 in 1983, 28 in 1984, 29 in 1985), and 14 fewer genera were collected with the three-kick method during the same time period (46 in 1983, 37 in 1984, 32 in 1985). This declining trend was not observed in results from sampling the Le Sueur River (control). Richness also seemed stable at Site 2 (above the dam). The reduction appears related to the flow fluctuations caused by the peaking.

Community Diversity

Only Surber sample data was used for this parameter. Community diversity values were determined for four selected sites: 2(above reservoir), 5 (just below dam), 6 (downstream before Le Sueur River enters), and 7 (Le Sueur River, the control). Station 1 (Shallow) of site 5 showed the greatest change in diversity from 1983 to 1984 with 1985 remaining low. Migration of invertebrates from Station 1 (low) to Station 2 (deep) may account for the decrease in Shannon-Wiener indices at Station 1 of Site 5e and the relatively constant values obtained for station 2 of 5e. Shannon-Wiener scores for Site 6 showed less variation than Site 5 implying a gradient of impact proceeding downstream from the dam. The LeSueur River (Site 7) appeared to have stable community diversity throughout the study and was significantly higher in station 2 (deep) throughout the study period.

It should be noted that the values obtained in 1983 for both the Blue Earth River and LeSueur River systems were both environmentally stressed before the peaking began.

Functional Feeding Groups

Functional feeding groups reflect availability of different types of food and are related to stream order (stream-river size).

The collectors (gatherers and filter feeders) were the dominant functional feeding group which is consistent with the River Continuum Concept for a sixth order river. The most impacted site was Site 5e at both stations, although the shallow water areas (Station 1) were more important to shredders than the deeper water at Station 2 which was habitat to a large number of collectors. The impact of flow on collectors, scrapers and predators diminished downstream. This implied that food and suitable habitats were available. Drifting invertebrates and fine particulate organic matter (FPOM) a primary food source from scouring of the riverbed (Ruff, 1987) probably provided the needed food source.

Even though abundance of the various functional groups were reduced below the dam, the percent composition remained fairly constant.

Conclusions

This study documented significant reductions in total abundance of invertebrates, loss of genera richness and decreased community diversity downstream of the dam. These negative impacts were most severe at Site 5e and seemed to lessen at Site 6. Although the Intermediate Disturbance Hypothesis (Ward and Stanford 1983; Stanford and Ward 1983) suggests that some level of disturbance favors community diversity and richness within a dynamic equilibrium of the stream environment, the manipulated flows at Rapidan Dam exceeded the optimal level of disturbance that promotes maximum community diversity.

Overall Conclusions

The reservoir itself, during run of the river electric generation, appeared to have some positive and few negatives associated with it for the parameters studied. The positives included the reservoir decreasing the downstream concentration of Total Phosphorous, Filterable Phosphorous, Total Non-Filterable Residue and Total Volatile Non-Filterable Residue as well as Coarse Particulate Organic Matter. Further, the reservoir acted as a sediment trap in the 1984 and 1985 early periods (June-July) with no apparent effects in the late periods (August-September) even though the wet/dry cycle reversed itself. The reservoir acted as a trap for the pthalates (synthetic organics) even during peaking. As a negative the reservoir appeared to increase Nitrate-Nitrogen, which may have been due to the oxidation of Ammonia.

Negative impacts from peaking were observed in all four study categories of Water Quality, Sediments, Synthetic Organics and Aquatic Macroinvertebrates. However, most of the impacts were short term, acute and related directly to the peaking cycles. Sedimentation in the reservoir and the below dam aquatic macroinvertebrate changes (as a consequence of acute fluctuations in water quality and quantity) were long term changes. From a water quality perspective, all three sites below the dam revealed higher levels than baseline (June-September) for Organic Nitrogen, Total Phosphorous, Total Non-Filterable Residue and Total Volatile Non-Filterable Residue. The pre-event, startup, to maximum during the three events revealed that in 84 of 91 cases, the events raised the maximum concentration of the parameters; in some cases (i.e. Ammonia) up to 10 times. The Organic Matter in transport increased with events from pre-event in 33 of 36 cases, ranging up to 500 percent. That the increases were often greater progressively downstream implicates rewetting of the river bed, an area requiring further study. The sediment data revealed that the pre-event was surpassed during each event at all sites for suspended sediments. The synthetic organics data (pthalates) showed significant fluctuations at Site 3. The macroinvertebrate component documented significant reductions in total abundance, richness and species diversity downstream of the dam due to peaking.

The findings of this study document one of several consequences of conversion to peaking (i.e. also economics of electrical generation, fisheries, etc.) that need to be weighted in the final decision of switching from run of the river to a peaking generation option. The findings also apply to the option of maintaining the dam and reservoir as a run-of-the-river operation.

NEEDS

> "The practice of dam removal has outpaced the building of a scientific formulation, leaving a gap in applicable knowledge from which to approach the act of dam removal. Dam removal is advocated as an environmental restoration tool, and while preliminary anecdotal data offer some support for this assumption, sufficiently quantitative and/or long-term studies of physical and biological responses do not exist even though a significant number of dams have been removed."
> (Doyle, M.W. et al. 2000).

> "The removal of dams is becoming an increasingly realistic and preferred option in river management. The task remaining for engineers and scientist is to develop a base of knowledge from which to guide decisions surrounding dam removal. Unfortunately no data exists on pre- and post-removal conditions."
> (Doyle, M.W. et al. 2000).

> "Dam removal is sometimes portrayed as a very simple process, whereby all that needs to be done is to open up the dam and let nature heal itself. A comprehensive environmental assessment of dam removal and reservoir retention alternatives is necessary to overcome both the often simplistic view of dam removal and to establish a more complete understanding of both restoration and retention alternatives."
> (Shuman, J.R. 1995).

Rapidan Dam is in a unique position to meet the needs articulated above because it has run-of-the-river (pre-peaking) and peaking impact data, two of the options under consideration. Key parameters, those showing large fluctuations, should be re-run now that the river has reached equilibrium with the new hydrologic regime. This should be done whether or not there is a change in function and/or operation. If there is a change in dam function, ie removal, there then should be an immediate investigation upon completion and longer term follow up once the river reaches equilibrium.

This is an opportunity for Blue Earth County, the MPCA, the MDNR and appropriate engineering firm to continue the leadership role they have in place with Rapidan Dam. Dr. Emily Stanley, a leader in the field of dam removal from the University of Wisconsin, states:

> "Unfortunately/surprisingly, there isn't really much else on sediments and dam removal out there beyond the works that we've done (good for us, not so good for dealing with dam removals!)"
> (Stanley, E. 2004).

This again emphasizes the need for pre and post studies and I hopefully have indicated the unique position and opportunity Rapidan possesses.

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The full Research Project Report and the Executive Summary are available on the Minnesota River Basin Data Center: Water Resources Center, Minnesota State University Mankato. http://mrbdc.mnsu.edu

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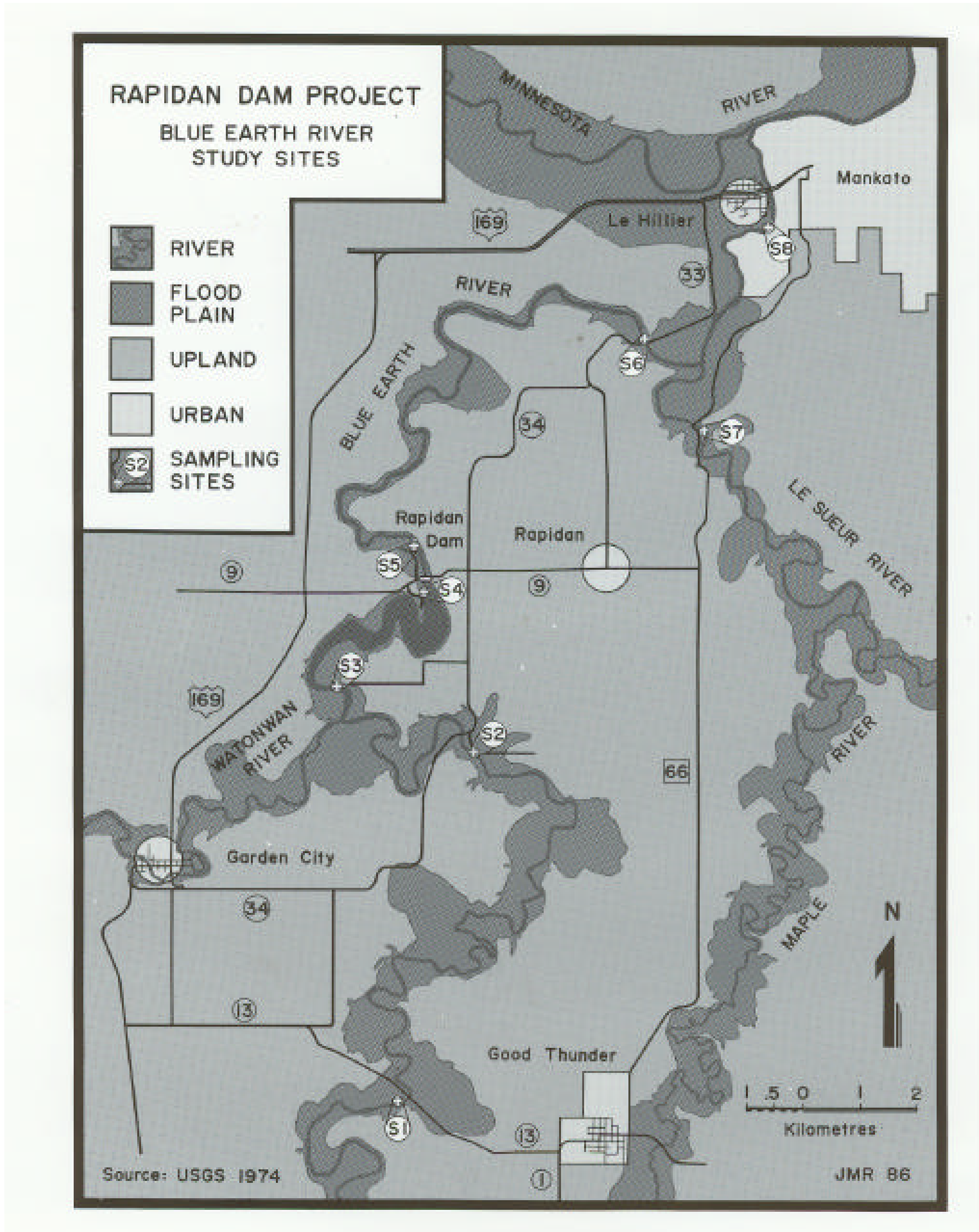
ATTACHMENT #1: Location of sampling sites in the study area

Figure 2 from the Rapidan Dam Research Project: Environmental impacts of converting a run-of-the-river low head hydroelectric dam to a peaking operation.



ATTACHMENT #2: Reservoir transects and sampling sites, July 1985

Figure 73 from the Rapidan Dam Research Project: Environmental impacts of converting a run-of-the-river low head hydroelectric dam to a peaking operation.